The Journal of Anatomical Sciences
Email: journalofanatomicalsciences@gmail.com

J. Anat Sci 14(2)

The Impact of Burning on Decomposition Timeline: A Comparative Study Between Burnt and Strangulated Porcine Carrions

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ABSTRACT

Crimes involving fire are becoming increasingly common, and criminals often use fire to mask the actual cause of death, conceal the identity of the victims, and hide evidence related to the crime scene. This study was designed to compare the decomposition timeline between burnt and strangulated porcine carrions to evaluate differential decomposition timeline involving burnt and strangled victims. This research was done in the Department of Anatomy and Forensic Anthropology Research Facility (DAFARF) in CRUETCH, for a period of 30 days.

Four pigs (*sus scrofa domestica*) weighing 30-35 kg each were used as animal models. Two pigs were burnt to death using scale 1 of Crow-Glassman burning scale, and two pigs were sacrificed through strangulation. Immediately death was confirmed, all pigs were enclosed in wire mesh cages and left on the open earth surface drifted 10 metres apart. Physical observations for postmortem changes taken through total body score, collection of insects for entomological analysis, as well as core and ambient temperature readings were recorded. Total body scores were assessed to observe regional decay rates and patterns between the carrions. Soil before and after the experiment were collected for physicochemical analysis and volatile fatty acids. The result showed that the burned carrion decomposed faster with statistically significant ($p<0.01$) higher values recorded in total score of the burnt carrion when compared with strangulated carrion. Injuries from the flames were observed to have propagated and increased the rate of decomposition. So physicochemical parameters had similar impact on both carrions, with no statistically significant ($p<0.01$) difference between the burned and strangulated carrions. This result may avail forensic experts the requisite knowledge of decomposition science associated with differential modes of death and proper application in estimation of postmortem interval.

Keywords: decomposition, taphonomy, burnt, strangulation, carrion.

INTRODUCTION

The determination of decomposition timeline has been a primary concern in taphonomy research [1]. The rate of decomposition of porcine carrions depends on a variety of factors such as weather condition, soil texture, insect activity and temperature [2]. From the recommendation of using domestic pig cadavers as analogues for humans in forensic entomology in the 1980's, pigs became the most frequently used model cadavers in forensic science [3], which in a way shaped our understanding of how large vertebrate cadavers decompose.

Decomposition is the process whereby living organisms break down into smaller matter. It begins immediately after death by autolysis - the breakdown of tissues by the body's own bacteria (chemicals and enzymes) and putrefaction - the breakdown of tissues by bacteria [4]. Prime decomposers are bacteria and fungi, though larger scavengers also play an important role in decomposition if the body is accessible to insects, mites, and other animals [5]. The stages of decomposition are fresh, bloat, active, decay, advanced decay and dry remains [4]. The fresh stage starts from when the heart stops beating. From the moment of death, algor mortis sets in, this is also known as the cooling of death. Within three to six hours of death, the muscles become rigid, leading to a stage called rigor mortis, since blood is no longer pumped [6].

The bloat stage is when aerobic metabolism takes place leading to accumulation of gases such as hydrogen sulphide, carbon dioxide, methane and nitrogen [7]. These gases cause distention of the

abdomen and the entire trunk, enhanced by intestinal anaerobic bacterial causing slippage of skin, purging of gases that will result in strong distinctive odours [8]. Active decay is where the carrion loses its mass due to the feeding by maggots and other insects. At this stage, liquefaction of tissues and disintegration become apparent, and the strong odours continue to persist [8]. During advanced decay, insect activity is reduced. The area where the porcine died will show signs of vegetation death, there will be increase in soil nutrients such as potassium, calcium, and nitrogen [8-9]. At the dry stage, the parts of the remains are dry and might also be bleached if it was exposed to elements. Skeletonization can be either partial or complete depending on presence or absence of some soft tissues [8-9].

Some of the factors that affects the rate of decay include: temperature, availability of oxygen, prior embalming, cause of death, burial, access by scavengers, trauma, humidity, rainfall, body size, clothing and exposure to elements, of which a carrion that has been exposed to open elements such as water and air will decompose quickly and attract much insect activity than a body that is buried or confined in special protective gear or artifacts [10]. Manner of death have not been reported by other authors to have obvious effects on the insect activity or successional pattern on the carcass, but other works have reported the impact of mode of death, relative humidity, temperature, depositional environment and body size [11].

In this study, the focus was to determine the rate of decomposition of burnt and strangled porcine carrions in a typical rain forest of Cross River State, Nigeria. Burnt bones often evoke questions as to the timing of burning events [12]. The essence of the study was to determine the progression of thermal damage on bones with advance in decomposition. Pigs were studied to find out the effect of heat stress on them [13].

Building on existing research [14-17], this study sought to discover the role of fire in the decomposition timeline, to determine the difference in decomposition rate of burnt and strangled porcine carrions. It was noted that determination of decomposition timeline is vital in taphonomy and forensic cases, it enables researchers to confirm the role of certain factors such as fire in the rate of decomposition [17]. Several factors can accelerate or inhibit the rate of decomposition. Such variables include ambient temperature, humidity, rainfall, depth of burial, and presence/absence of clothing [18].

MATERIALS AND METHODS

This study was carried out at the Department of Anatomy and Forensic Anthropology Research Facility (DAFARF), located in the outskirts of the campus, and exclusively reserved for forensic taphonomy studies.

This study cohort involved four pigs (*sus scrofa demosticus*) six-month-old, weighing between 30-35 kg for the burnt and strangulated carrion. The four (4) porcine models were bought from Okuku central market and were simultaneously sacrificed, two burnt up to level 1-2 of crow Glassman scale, while the other two were strangled to death. Immediately death was confirmed using a stethoscope, the rectal and ambient temperatures was noted. The remains were laid laterally on the ground and protected by square wire mesh cages to protect the carrion from scavengers. The first observations were made in the first 8 hours, where early postmortem changes were noted. Observations were made three times daily for the first two weeks and reduced to twice daily for the last sixteen days. This study lasted for 30 days according to the design to monitor the progress in decomposition record daily ambient temperature (minimum and maximum).

The gross postmortem changes were regularly assessed and recorded in both burnt and strangulated carcass and the decomposition stages were photographed at each visit to the site. Insects were caught using aerial nets and were stored in sample bottles containing 10% formaldehyde to preserve them for subsequent analysis and identification by the forensic entomologist.

Insects Collection

Insects were collected from two of the pigs using insect net, the state of the carrion and stage of decomposition were documented with written reports and photographs. Insects present on, around, and under the carcass were collected manually by hand-picking after searching for about 15-20 min. The head and legs of the carcass were lifted for proper search of sample underneath. All insects were preserved using formalin solution and stored for identification. Qualitative assessment of insect abundance (in addition to recording presence/absence) was made during each collection.

Body Scoring Method

The degree of body decomposition was quantified using Total Body Score (TBS), a scale frequently used in taphonomic studies to examine the progress of decay. In this study both onsite scoring and the use of photographs were employed to get the total body score. The scoring was done at every visit to the research site and pictures taken. For every day of observation, the three main parts of the carrion were assigned points depending on how fast they had decomposed. The body segments were scored three

times daily (morning, afternoon and evening) based on three segments of the carrion: head and neck, trunk, and limbs according to Megyesi *et al* [9].

Research Analysis

The data obtained were statistically analysed using statistical package for social sciences (SPSS) version 25 and Microsoft word Excel windows 365 to present the numeric data involving temperature and Total body for prediction PMI. The line graphs and scattered plots were generated using Microsoft word excel windows 365 and statistical package for social sciences Version 25. Pre and post sand analysis was done by experts from department of Soil Science and Land Resources, Faculty of Science University of Uyo, Uyo, Nigeria.

RESULTS

The outcome of the descriptive statistics showed the results of mean values as well minimum and maximum values of the total body score for the period of thirty days (30) days. A statistically significant difference ($p<0-01$) was noted between the TBS values of burnt and strangulated porcine models (Table 1).

Table 1: Descriptive statistics of total body score (TBS) of burnt and strangled porcine carrions for 30 days

Modes of Death	Mean±SD	Minimum	Maximum
Burned Carrion	14.65±1.22	6.00	30.00
Strangulated Carrion	11.82±1.04	3.00	24.00
Total	13.045±1.45	3.05	28.00

Values with similar superscripts are statistically significant different at $P<0.01$.

Table 2: Physicochemical analysis of soil organic matter for both porcine carrions.

	PH (H_20)	EC ds/cm	DEPTH (FT)	SAND %	SILT %	CLAY %	Base Saturation %	SOC %	SOM %	Soil Colour (Chrome)	Soil Texture
Pre	4.74	0.05	0.00	81.47	6.78	11.31	79.18	1.07	1.88	5Yr 5/8	Sand
Post	3.96	0.09	0.00	83.73	5.93	9.41	78.19	1.16	2.12	5Yr 6/8	Clay Loam

Key: PH= Amount of Hydrogen ion present or the quantity of acidity or Alkalinity; **EC**= Soil electrical conductivity, **DEPTH**= How deep is the grave, **SOC**= Soil Organic Carbon, **SOM**= Soil Organic Matter

It was observed from the results presented in table 2, that there was significant increase in the soil pH from 4.74 to 3.96. This infers that carrion decomposition science plays a role in the soil pH.

Table 3: Physicochemical analysis of soil exchangeable bases for both porcine carrions

	AP Mg/Kg	K	Na	Ca	Mg	EA	ECEC	TN %
Pre	14.76	0.08	0.06	4.43	3.11	1.92	9.60	0.08
Post	11.96	0.05	0.03	3.22	2.92	1.14	7.36	0.09

Key:

AP= Available Phosphorus, **K**= Potassium, **Na**= Sodium, **Ca**= Calcium, **Mg**= Magnesium, **EA**= Activation energy, **ECEC**= Effective cation exchangeable capacity Total amount of exchangeable cations (Potassium, Sodium, Calcium and Magnesium), **TN**= Total Nitrogen.

Figure 1: Showing visible postmortem changes of burnt and strangled carrions at day 1 (A&B), 2 (C&D) and 3 (E&F) respectively showing differential visible postmortem changes

Figure 1 showed decomposition matrix of burnt and strangualated porcine models left on open earth surface for three days after death. The physical postmortem changes showed differences in decay patterns and rates between the two carrions. It was observed from the total body score that the burnt carrion decomposed faster than the strangulated carrion.

Figure 2: Showing visible postmortem changes of burnt and strangled carrions at day 7 (A&B), 14 (C&D) and 30 (E&F) respectively showing differential visible postmortem changes

The result in Figure 2 showed the decomposition rates and patterns between the burnt and strangualated porcine remains is different based on physical postmortem chnages, as the impact of mode of death on decay rates is seen also in higher values recorded in total body score in Table 1.

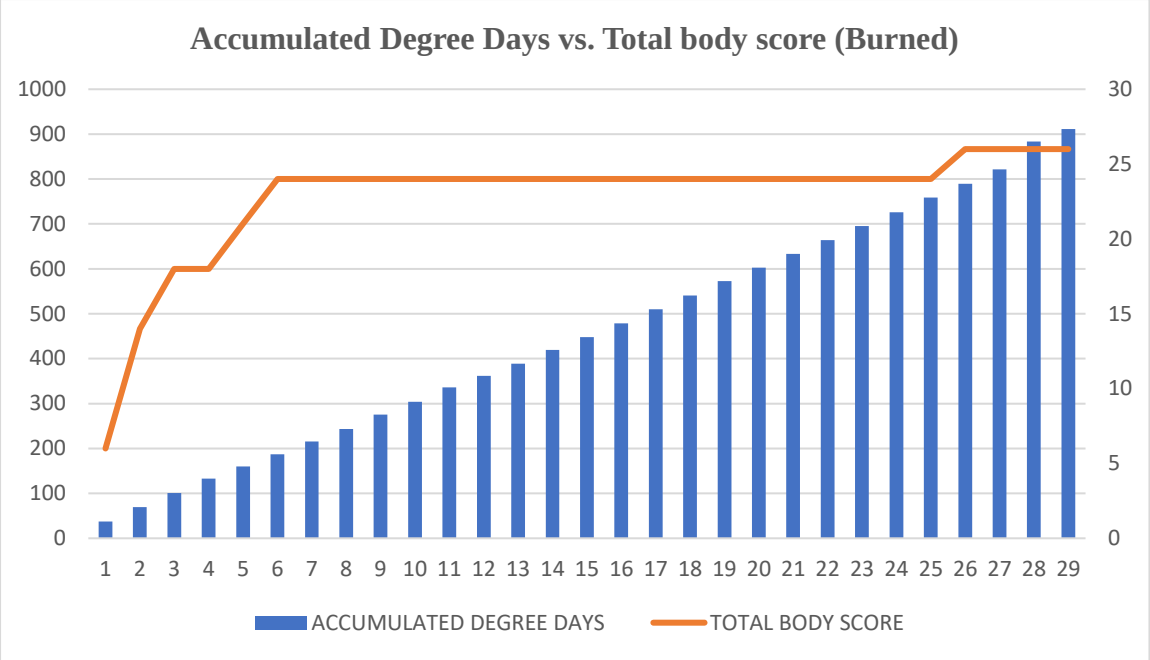

Figure 3: Accumulated Degree Days vs. Total Body Score (Burned)

As observed in Figure 3, showing the values of Accumulated Degree Days vs. Total body score for the burnt carrion, the ADD value increased gradually until it reached a final value of 911.7 ºc. The table shows that the TBS score increased quickly for the first 5 days and then stayed constant till day 26 where it stays constant again at a final TBS value of 26.

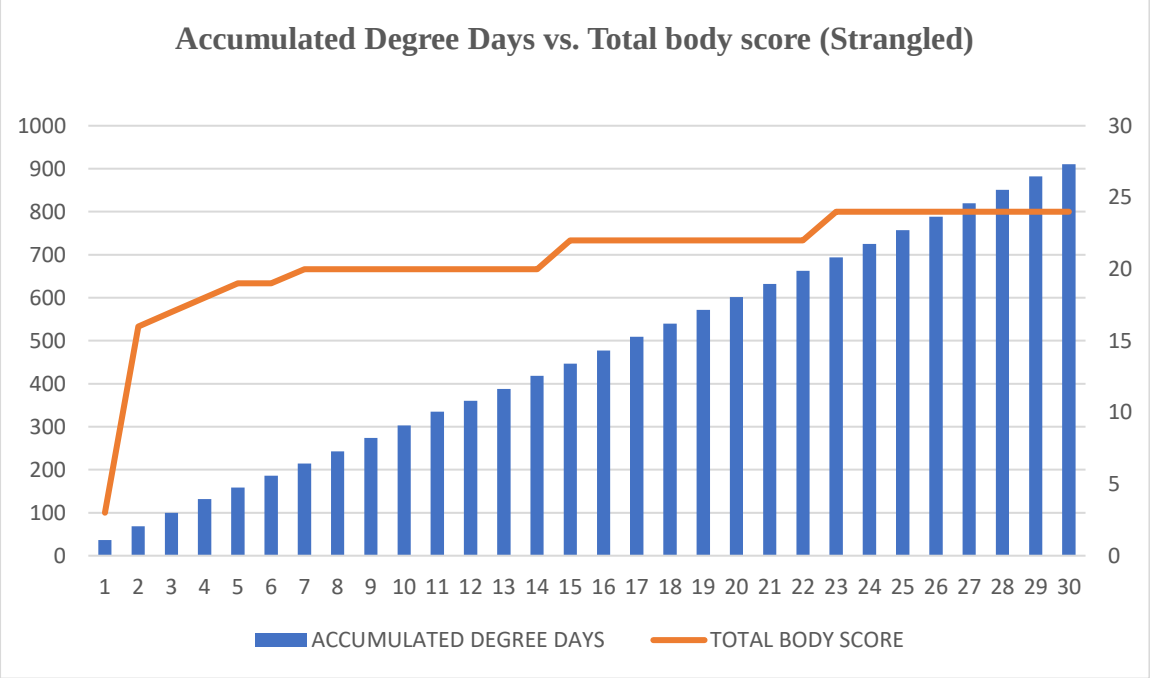

Figure 4: Accumulated Degree Days vs. Total Body Score (Strangled)

As seen in Figure 4, showing Accumulated Degree Days vs. Total Body Score, the ADD value increased gradually until it reached a final value of 901.3 ºc. The graph showed that the TBS score wavered for the first 6 days and then stayed constant at 20 till day fifteen (15) where it stayed constant again till day 23. From day twenty-three (23) till day thirty (30), the Total body score value of 24 remained constant till the end of the observation.

Discussion

The comparison of decomposition timeline is a major step for forensic scientists to understand better the rate of decomposition and why it follows a particular pattern. This study was conducted to determine the role of mode of death (fire) on the decomposition timeline, and to compare the rate and stages of decomposition between the strangled and the burnt carrion. Gross observations from this study revealed that the burnt pig decomposed faster and mummified because of the high ambient temperature and its mode of death while the rate of decomposition in the strangled carrion was slower compared to the burnt carrion.

Both carrions passed through the five stages of decomposition categorised by Megyesi *et al* [9] although the bones were not totally exposed at the skeletal stage of both carrions. Using several factors like Accumulated Degree Days, Total Body Score, Glaister equation, and insect succession pattern, the estimation of the Postmortem Interval was made easy. The factors that affect the rate of decomposition were also studied in this research. In 1989, Galloway and other colleagues researched on some of these factors, including temperature, accessibility by insects, and humidity [18-20]. The insects were active, and they served to propagate the rate of reaction as well. In another research on the impact of insect activities on the rate of decomposition, it was discovered that their study on insects detected, located, and evaluated the remains, followed by the colonisation and post colonisation phase as the remains were consumed, over time this predictable succession pattern has been used to calculate postmortem interval [17].

Stages of Decomposition

The stages of decomposition have been earlier registered by Megyesi *et al*, in 2005, and were later modified by Zhou and Bryard [2] and subsequently by Connor *et al* [4] even though they categorised decay stages as Fresh, bloated, early decomposition, advanced decomposition, and skeletonisation. From the observations made at the site, it was observed that the strangled carrion exhibited less intense postmortem changes, unlike the burnt carrion which had more accelerated decomposition at the beginning due to the application of fire. At the fresh stage, the strangled carrion maintained its pink skin with moderate insect activity. Palor mortis (coolness of death) began to set in few hours into the first day of the study, as well as rigor mortis in the orbit, neck, and upper limbs. During the fresh stage, the burnt pig on the other hand had blisters that exposed reddish skin. Most part of the hair was singed accompanied with flaking of the epidermis.

The bloating stage was evident in the strangled pig as early as day 1 and it progressed up to day 3 when the bloating began to wane, accompanied with greenish discoloration and discharge of fluid. The bloating proceeded to an advanced bloating stage by the 2nd day of the study. The bloating in the burnt pig was much understated and was cut short by day 2 since there was an outburst of the inguinal region.

By day 3, there was an onset of fresh decay in the strangled pig which was characterised by sagging of the flesh, fluid discharge, and putrid smell. There was a noticeable slippage of the skin. By the end of day 3, the strangled pig was still at the late stage of fresh decay. The burnt remain hit active decay stage earlier than the strangled pig because of the initial sagging of skin which led to an outburst of the inguinal region with gushing out of the abdominal content as early as day 2. At the crime scene, one of the main tasks was to figure out the decomposition timeline and the stages of decomposition in the two carrions. Galloway [16] already derived a series of decay stages based on data gathered from the arid environment of Arizona which are fresh, early decomposition, advanced decomposition and skeletonisation.

The onset of active decay in the strangled pig started on day 4. The rate of the active decay was slow, for two days the carrion seemed to be in affixed state, and the only noticeable change was a reduction in the size of the carrion. The active decay started in the burnt pig as early as day 3 mostly in the abdominal region, at first the head, neck, and limbs were relatively fresh, and it progressed into the anterior abdominal wall and the fore limbs.

For the skeletonisation stage, bone exposure began in the strangled pig by day 6. The bones of the fore and hind limbs in contact to the ground began to be exposed, alongside the nasal bone. At some point, the bones of the rib cage became very palpable after some days of the study, while bones of the fore limbs began to get dismembered. The intense regional skeletonization progressed by day 25. Bone exposure began in the fore and hind limbs of the burnt pig by day 5, with less than half of the area being scored. By day 6, there was further exposure of the lumbo sacral region of the spine, the skull, ribs, and pelvic region. The skeletonization stage was slowed down by the burnt, mummified skin, and the mummification occurred alongside dry decay. At the end of the study, the exposed bones were dismembered, and they began to detach from each other. Generally, from the study observations, the burned carrion decomposed faster than the strangulated carrion from the results of total body score.

Total body Score

The total body score (TBS) of the fresh pig began at the lowest point which is a total of 3 (Fresh stage) and then it progressed rapidly in the next two days before it became relatively stagnant from day 4 to day 22, after that the total body score increased again for the last 8 days of observations.

The impact of the fire caused the TBS of the burnt pig to be as high as 6 on the first day of observation, this number increased significantly over the next few days before it halted. From day 5 to day 28 the carrion's total body scores remained fixed and it seemed as if it wouldn't change until day 29 where it increased again, the decay rates.

In previous research, Megyesi *et al,* [9]. divided the human body into three regions which are the head and neck, the body, and the limbs, because these body parts decompose in a different way and at different rates entirely. Each body region was assigned six stadia with corresponding scores (with lowest score of one (no visible changes) and the highest six (complete skeletonisation). Every stage contained specific decomposition phenomena, but these were not assigned a separate score, because they can occur at the same time or one by one.

Accumulated degree days

Accumulated degree days (ADD) are one of the most key factors used to determine the postmortem interval of a body [17]. Concerning ADD, the data gotten has a lot of uses including estimating the postmortem interval from decomposed human remains [9]. This study was conducted to compare the decomposition timeline between burnt and strangled carrion, and it is important to note that decomposition is not just dependent on the time of death but also on the ADD [9]. The ADD progressed exponentially in both carrions to reach a final temperature of 911.7ºc and 910.3ºc for burnt and strangled carrions, respectively. Here it showed that as ADD increased, the TBS also increased from day 1-30, even though mummification observed in both carrions at some points stagnated the TBS values.

Soil Physicochemical and Exchangeable Bases

The soil is another principal factor that can affect the rate of decomposition. When vertebrate cadavers decompose, they release copious amounts of nutrients into the soil, changing the soil composition, even though soil is very vital in cracking forensic cases, its impact is rarely studied Szelecz *et al* [12]. Before the experiment began, the soil at the site of the burnt carrion had decreased levels of K and Mg than after the decomposition of the carrion. In the pre-experiment phase, the soil surrounding the burnt carrion had a sandy texture, but this changed to be clay-loamy texture in the post-experiment phase. Meanwhile the level of Nitrogen increased after decomposition by 0.01%.

The soil samples collected from where both carrions were deposited showed that the sand had higher levels of Mg, K, Na, and Ca. The level of these elements dropped after the decomposition of the carrion. In the pre-experiment phase, the soil texture changed from sandy to clay-loamy texture probably due to the fluid released in the carrion decomposition island. Elements like Nitrogen increased in level after the decomposition of the carrion by 0.03%. Overall Nitrate content unusually increases at the beginning of the experiment [12, 18]

Conclusion

This study provides additional information about the comparison between the decomposition rate and patterns of burnt and strangled carrions based on several factors such as temperature, insect succession and soil type. The knowledge of contrasting decomposition science between the two modes of death will avail forensic investigators the requisite idea to predict accurately the postmortem interval when saddled with the responsibility of human identification.

Conflicts of Interest

No conflicts of interest between authors.

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